and configured to capture thermal energy from high-aspect-ratio heat sources, such as pipes;

[0027] FIG. **11**B is a schematic, isometric view of another energy harvesting system having a plurality of heat engines and configured to capture thermal energy from high-aspect-ratio heat sources and counter-flowing cooling sinks;

[0028] FIG. **12** is a schematic, fragmentary cross-sectional view of a round, three-dimensional SMA working element for use in large-scale heat engines;

[0029] FIG. **13** is a schematic, side view of a portion of a large-scale heat engine having stacked and layered SMA working elements; and

[0030] FIG. **14** is a schematic, plan view of a heat engine having a single SMA working element, which forms multiple loops but is welded or joined at only two locations.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] Referring to the drawings, wherein like reference numbers correspond to like or similar components whenever possible throughout the several figures, there is shown in FIG. **1** a heat recovery system or energy harvesting system **10**. Features and components shown and described in other figures may be incorporated and used with those shown in FIG. **1**. The energy harvesting system **10** shown includes a heat engine **14** and a driven component **16**.

[0032] The energy harvesting system **10** utilizes a first fluid region or a hot region **18**, having a first temperature. The hot region **18** may be in heat transfer communication with a heat source, such as waste heat, or may represent any region of relatively warm temperature to contribute to operation of the heat engine **14**, as described herein. The energy harvesting system **10** also utilizes a second fluid region or a cold region **20**, having a second temperature, which is generally lower than the first temperature of the hot region **18**. The cold region **20** may be in heat transfer communication with a cooling source, such as such a cold fluid, or may represent any region of relatively cool temperature to contribute to operation of the heat engine **14**, as described herein. The designation of the hot region **18** and the cold region **20**, or the temperatures associated therewith as either "first" or "second" is arbitrary and is not limiting.

[0033] The heat engine **14**, as described herein, is configured to convert thermal energy from the temperature differential between the hot region **18** and the cold region **20** into mechanical energy. The driven component **16** of the energy harvesting system **10** may be configured to be driven by the mechanical energy or power generated from the conversion of thermal energy to mechanical energy within the heat engine **14**.

[0034] The driven component **16** may be a mechanical device, such as, without limitation: a generator, a fan, a clutch, a blower, a pump, a compressor, and combinations thereof It should be appreciated that the driven component **16** is not limited to these devices, as any other device known to those skilled in the art may also be used. The driven component **16** may be operatively connected to the heat engine **14** such that the driven component **16** is driven by the heat engine **14**.

[0035] More specifically, the driven component **16** may be part of an existing system, such as a heating or cooling system and the like. Driving the driven component **16** with mechanical energy provided by the heat engine **14** may also allow an associated existing system within the energy harvesting system **10** to be decreased in size and/or capacity or eliminated entirely.

[0036] Additionally, the mechanical energy produced by the energy harvesting system **10** may be stored for later use or as an auxiliary energy supply. In vehicles or power production facilities, the energy harvesting system **10** increases the overall efficiency of the vehicle or production facility by converting what may have been waste thermal energy into energy for current or later use.

[0037] The driven component **16** may be a generator or an electric machine (which may be referred to as a motor/generator) configured to convert the mechanical energy from the heat engine **14** into electricity **30** (as schematically shown in FIG. **1**). Alternatively, the driven component **16** may be attached to, or in communication with, a generator. The driven component **16** may be any suitable device configured to convert mechanical energy to electricity **30**. For example, the driven component **16** may be an electric machine that converts mechanical energy to electricity **30** using electromagnetic induction. The driven component **16** may include a rotor (not shown) that rotates with respect to a stator (not shown) to generate electricity **30**. The electricity **30** generated by the driven component **16** may then be used to assist in powering one or more electric systems or may be stored in an energy storage device.

[0038] The hot region **18** and the cold region **20** may be sufficiently spaced from one another to maintain the temperature differential between the two, or may be separated by a sufficient heat exchange barrier **26**, including, without limitation: a heat shield, a Peltier device, or an insulating barrier. The heat exchange barrier **26** may be employed to separate the heat engine **14** into the hot region **18** and the cold region **20** such that a desired temperature differential between the hot region **18** and the cold region **20** is achieved. When the heat exchange barrier **26** disposed between the hot region **18** and the cold region **20** is a Peltier device, such as a thermoelectric heat pump, the heat exchange barrier **26** is configured to generate heat on one side of the barrier **26** and to cool on an opposing side of the barrier **26**.

[0039] The hot region **18** and the cold region **20** of the energy harvesting system **10** may be filled with, for example and without limitation: gas, liquid, or combinations thereof. Alternatively, the hot region **18** and the cold region **20** may represent contact zones or contact elements configured for conductive heat transfer with the heat engine **14**.

[0040] The heat engine **14** is configured to utilize temperature differentials between the hot region **18** and the cold region **20** in the energy harvesting system **10** in areas such as, without limitation: vehicular heat and waste heat, power generation heat and waste heat, industrial waste heat, geothermal heating and cooling sources, solar heat and waste heat, and combinations thereof. It should be appreciated that the energy harvesting system **10** may be configured to utilize temperature differentials in numerous other areas and industries.

[0041] Referring now to FIG. **2**, and with continued reference to FIG. **1**, there is shown a more-detailed schematic view of the heat engine **14** shown in FIG. **1**. Other types and configurations of heat engines may be used with the energy harvesting system **10** shown in FIG. **1**. FIG. **3** shows another heat engine **54** which may also be used with the energy harvesting system **10** shown in FIG. **1**, and includes many similar components and functions similarly to the heat engine **14**.